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CORROSION EVALUATION OF TEST WELDS ON M.V.ARCTIC

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CORROSION SECTION

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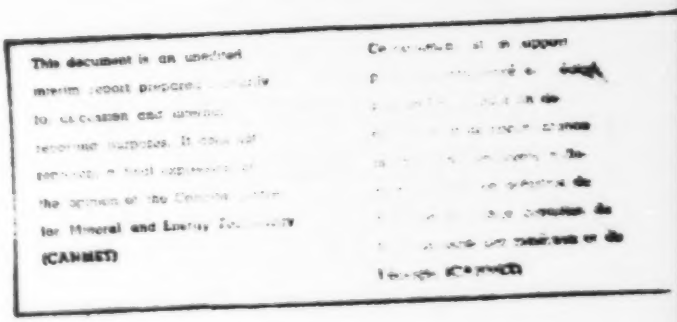
METALS TECHNOLOGY LABORATORIES



REPORT: MTL 88-13(TR)

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CORROSION EVALUATION OF TEST WELDS ON M.V. ARCTIC

by

V. Mitrovic-Scepanovic and R.J. Brigham

ABSTRACT

The CANMET tank testing procedure was used to determine the corrosion characteristics of three grades of steel (Grade A, Grade E and Grade EH) in combination with five consumables. The coupons tested were fabricated to replicate test welds left unprotected on the hull of M.V. Arctic. Two forms of corrosion, i.e., weld-metal corrosion and heat-affected-zone corrosion were observed, depending on the combination of baseplate and consumable chemistries.

LABORATORIES DE LA TECHNOLOGIE DES METAUX

RAPPORT: MTL 88-13 (TR)

EVALUATION DE LA CORROSION DES SOUDURES SUR LA COQUE DU NAVIRE M.V. ARCTIC

par

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RESUME

Le "test de reservoire" à CANMET a été utilisé pour déterminer les caractéristiques de la corrosion de trois aciers de type A, E et EH en combinaison avec cinq baquettes de soudage. Les échantillons qui ont été evalués étaient fabriqués comme des repliques des soudures sur la coque du navire M.V. Actic. Deux types de corrosion (attaque accéléré des métaux soudés ensembles et attaque de la zone thermiquement affectée) étaient observées selon la chimie des aciers et des baquettes de soudage.

INTRODUCTION

M.V. Arctic, the prototype of the Canadian Arctic Cargo Ship, fabricated in 1978 as Ice Class II, was refitted with a redesigned bow to upgrade it to Ice Class IV in 198 . The new class rating is expected to allow operations eight months per year in the Arctic; 50% of that time in ice. Consequently, the requirements for corrosion resistance became particularly important.

A contract, funded by the Canadian Coast Guard, was initiated to study weld-zone corrosion of test welds on the new hull of the M.V. Arctic as it occurs under actual service conditions. Parallel short-term and long-term laboratory corrosion tests with metallographic examination are included in the study to establish a correlation between in-service and laboratory corrosion rates as well as to develop general criteria for selection of welding consumables for low-temperature shipbuilding steels.

Independent corrosion evaluation of coupons fabricated to replicate the actual hull test welds using identical grade plates, consumables and procedures was performed at CANMET. The results obtained after six months of testing are presented in this report.

EXPERIMENTAL

Sections of the seventeen different welded laboratory coupons measuring 150 mm (6 in.) long were supplied by the CCG contractor for tank testing at CANMET (Table 1). Due to the size of the coupons, they were machined and joined to obtain eight trapezoids of the standard size required for the tank testing and

one half-trapezoid (Fig. 1, a-i).

Six steels (2 Grade A, 3 Grade E and 1 Grade EH) were used as baseplate material. These are C-Mn steels typical of those used in the past and current practice in the shipbuilding industry. Chemical compositions of the steels are given in Table 2. It should be noted that the Grade A plate containing 0.04% Si is semi-killed steel, whereas the other plates are fabricated from fully-killed steel.

Fabrication consumables were specified by the designers of the refit bow and hull on the basis of current practice. E48018 and EL12-F7A2 are regular C-Mn consumables typically used in shipbuilding applications. In addition, three trial consumables were selected on the basis of corrosion resistant chemistries. The CLA E48018 RCR is a prototype electrode developed in both high and low Si modifications by Canadian Liquid Air. The low Si version was used in this investigation. The ESAB OK.73.08 was originally developed specifically for weld-metal corrosion resistance. Both contain Cu and Ni additions with E48018 RCR having a considerably lower Si and Mn content. The E55018-C1 electrode was chosen for its high Ni content. As-deposited weld-metal chemistries are listed in Table 3.

The specimens were subjected to tank testing(1) for six months. The continuously aerated solution of 3.5% NaCl was held at 0-2 C. Depth of attack of the baseplate, weld-metal and heat-affected-zone (HAZ) was measured at two-month intervals after the removal of corrosion products. The maximum depth of attack, measured by a profilometer and confirmed by means of a

micrometer, was used as the criterion for the degree of corrosion.

RESULTS

WELD METAL CORROSION

The corrosion rates of weld-metal are given in Fig. 1. The data were averaged for all plate combinations except the semi-killed Grade A (19 mm) and plotted as a function of time. As shown previously (2-4), the weld-metal chemistries, particularly Cu, Ni and Si content, determine the corrosion resistance. The most corrosion resistant chemistry is not the one with the highest (Cu + Ni) content, namely E55018-C1, but the one with the lowest Si content in combination with Cu and Ni, E48018 RCR. A separate study of the effect of Si on the weld-metal corrosion rate is underway.

The low Si content associated with semi-killed steel (0.04% Si) has been shown to accelerate weld-metal attack[1]. In this case, the corrosion rate of plate 3 was more than twice the average rate; 1.85 mm after 6 months compared with an average of 0.9 mm.

HAZ CORROSION

Heat-affected-zone corrosion results from the difference between electrochemical potentials of the weld-metal and the baseplate adjacent to the weld, with the weld-metal being more noble. This type of corrosion has been found to be a function of Mn-content of the baseplate and appears to be associated with low temperature transformation products formed during cooling after welding.

The results given in Fig. 3 confirm the findings of the previous studies (2-4) and can be summarized as follows:

- Preferential HAZ corrosion was observed for Grades E and EH36 steels with Mn contents of 1.27 and 1.44 respectively.
- For Grade E baseplate, somewhat lower in Mn than Grade EH36, HAZ corrosion occurs only to a moderate extent in combination with most corrosion resistant consumables, i.e., E48018 RCR, E55018-C1 and OK.73.08 (specimens 15, 16, 17 in Fig. 1, f and g).
- Higher Mn content of Grade EH36 baseplate seems to be the reason for HAZ corrosion observed in combination with all consumables used in this study. The E48018 RCR and E55018-C1 consumables are clearly the most corrosion resistant and, consequently, are incompatible with the baseplate steel containing 1.4% Mn (specimens 19 and 20, Fig. 1, h and i).

SUMMARY OF RESULTS

Regular C-Mn consumables (i.e., E48018, EL23-F7A2) are more susceptible to preferential attack in the weld-metal than consumables containing Ni and Cu.

Among the Ni and Cu containing consumables, the most corrosion resistant is E48018 RCR, probably due to its low Si content.

Heat-affected-zone corrosion is observed for Grade E steel in combination with most corrosion resistant consumables and for Grade EH36 steel in combination with all five consumables used in this study. The degree of HAZ attack in EH36 steel was inversely

proportional to the corrosion resistance of the weld-metal.

REFERENCES

1. E. Rasanen and K. Relander, "Development of Shipbuilding Steel Plates for Use in the Arctic Seas", Scand. J. Metall 7 11 (1978).

2. R.J. Brigham, "Corrosion of Welds in Icebreaking Ships", Marine Engineering Digest 6 (2) 29 1986.

3. R.J. Brigham, M. McLean, V.S. Donepudi, S. Santyr, L. Malik and A. Garner, Report PMRL 87-56(J).

4. R.J. Brigham and V. Mitrovic-Scepanovic, Report PMRL 87-76(TR).

Table 1. TEST WELDMENTS

Weld Description and Process*	Heat Input (kJ/mm)	Baseplate/Weld Metal Combination (Steel Grade/Weld Metal Crown/ Steel Grade)	Laboratory Specimen I.D. Number
Original Hull, SMAW	1.1	(25 mm) A/E48018/EH36 (32 mm)	1
Original Hull, SMAW	2.0	(25 mm) E/E48018/A (23 mm)	2
Original Hull, SMAW	2.0	(19 mm) A/E48018/A (19mm)	3
Longitudinal Seam, SMAW	3.1	(32 mm) EH36/EL12-F7A2/EH36 (32 mm)	4
Transverse Butt, SMAW	2.9	(32 mm) EH36/E48018/EH36 (32 mm)	5
Transverse Butt, SMAW	2.9	(38 mm) E/E48018/EH36 (32 mm)	6
Longitudinal Seam, SAW	3.9	(38 mm) E/EL12-F7A2/E (38 mm)	7
Transverse Butt, SMAW	3.8	(47 mm) E/E48018/E (47 mm)	8
Transverse Butt, SMAW	3.0	(47 mm) E/ESAB-OK.73.08/E (47 mm)	9
Transverse Butt, SMAW	4.2	(47 mm) E/E55018-C1/E (47 mm)	10
Transverse Butt, SMAW	4.0	(47 mm) E/CLA-E48018-RCR/E (47 mm)	11
Transverse Butt, SMAW	2.7	(38 mm) E/E55018-C1/EH36 (32 mm)	15
Transverse Butt, SMAW	3.0	(38 mm) E/CLA-E48018-RCR/EH36 (32 mm)	16
Transverse Butt, SMAW	2.6	(38 mm) E/ESAB-OK.73.08/EH36 (32 mm)	17
Transverse Butt, SMAW	2.3	(32 mm) EH36/ESAB-OK.73.08/EH36 (32mm)	18
Transverse Butt, SMAW	2.5	(32 mm) EH36/CLA-E48018-RCR/EH36 (32mm)	19
Transverse Butt, SMAW	2.6	(32 mm) EH36/E55018-C1/EH36 (32 mm)	20

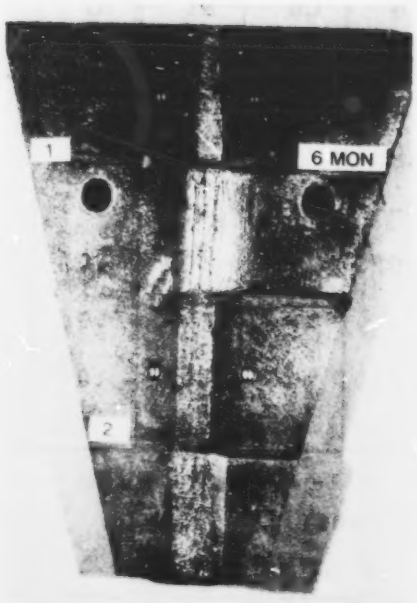
*SMAW = Shielded Metal Arc Welding, SAW = Submerged Arc Welding

Table 2. BASEPLATE CHEMICAL COMPOSITIONS (wt%)

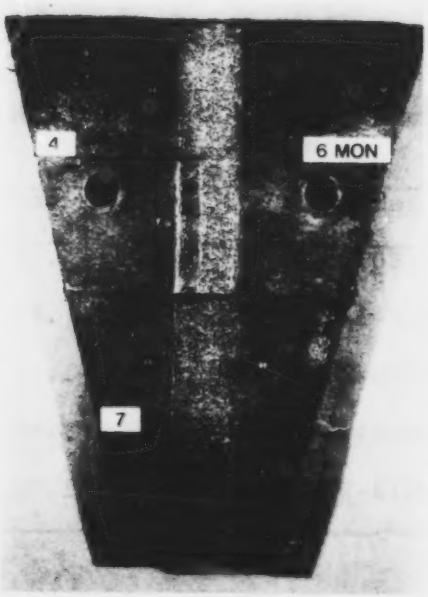
STEEL GRADE	THICKNESS (mm)	C	Mn	Si	P	S	Cu	Ni	Al	Cr	V
A	19	.23	.71	.04	.003	.013	.02	.02	--	.04	--
A	23	.14	1.04	.23	.011	.013	.02	.03	--	.04	--
E	25	.18	1.12	.25	--	--	--	--	.03	--	--
E	38	.23	1.27	.21	.006	.022	.03	.02	.01	.07	.02
E	47	.13	1.00	.23	--	--	--	--	.04	--	--
EH36	32	.19	1.44	.33	.010	.010	.26	.09	.04	.10	.07

Table 3. WELD METAL CHEMICAL COMPOSITIONS (wt%)

Electrode	C	Mn	Si	P	S	Cu	Ni	Cr	Mo
E48018	.074	1.04	.58	.010	.013	.04	.03	.05	.01
CLA-E48018-RCR	.056	.81	.16	.009	.011	.47	.51	.03	---
ESAB-OK.73.08	.082	1.18	.42	.010	.010	.32	.49	.07	.02
E55018-C1	.069	1.08	.39	.008	.012	.04	1.61	.05	---
EL12-F7A2	.057	1.72	1.11	.021	.019	.11	.05	.04	---



(a)



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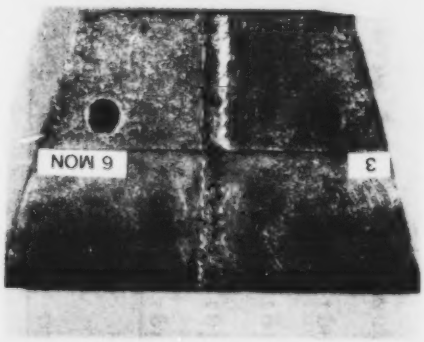
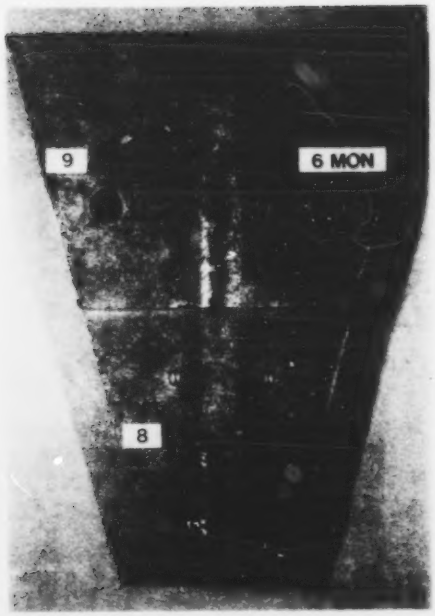


(b)

Fig. 1 (a) - (i) - Test Coupons after 6 months of tank testing.



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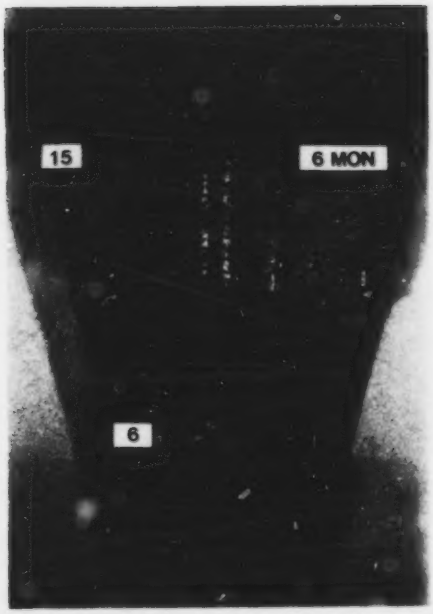

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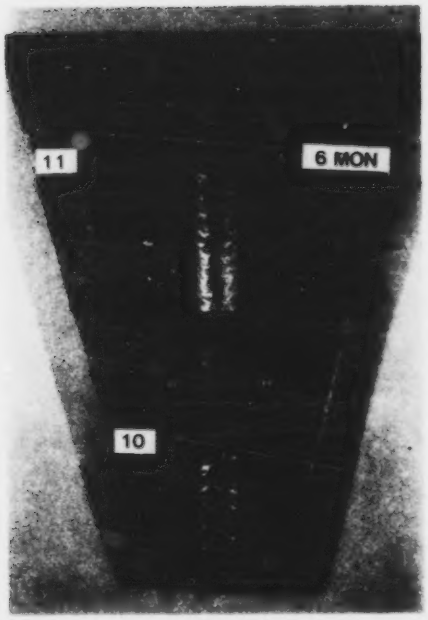

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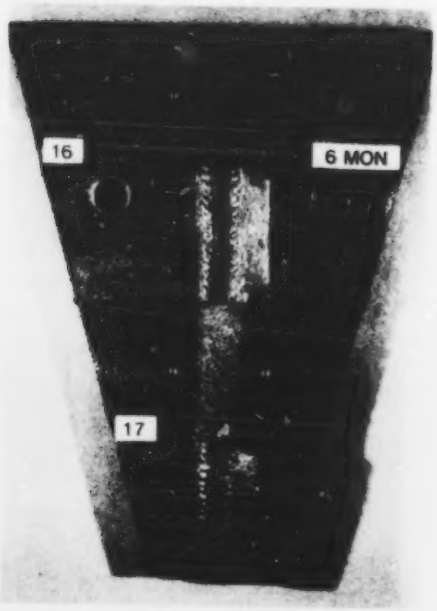

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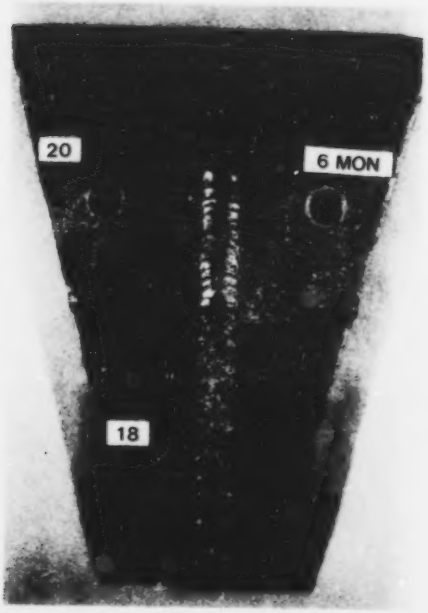
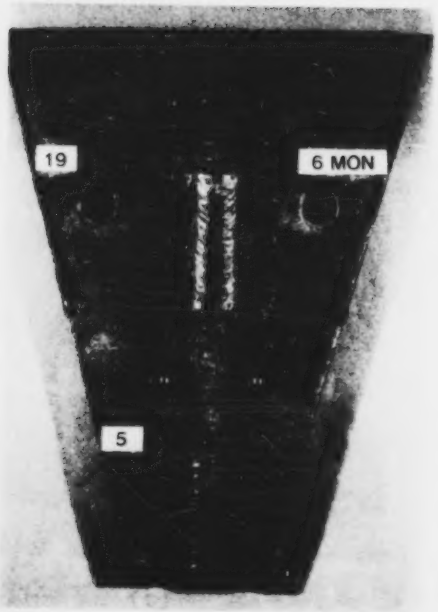


(i)



(h)

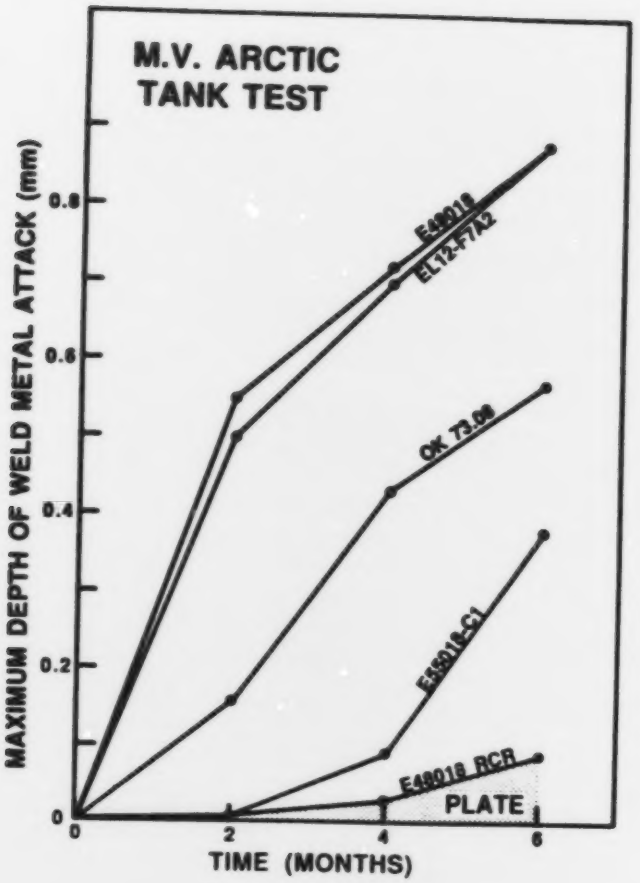


Fig. 2 Corrosion of weld metal as a function of time (Neg. 17577)

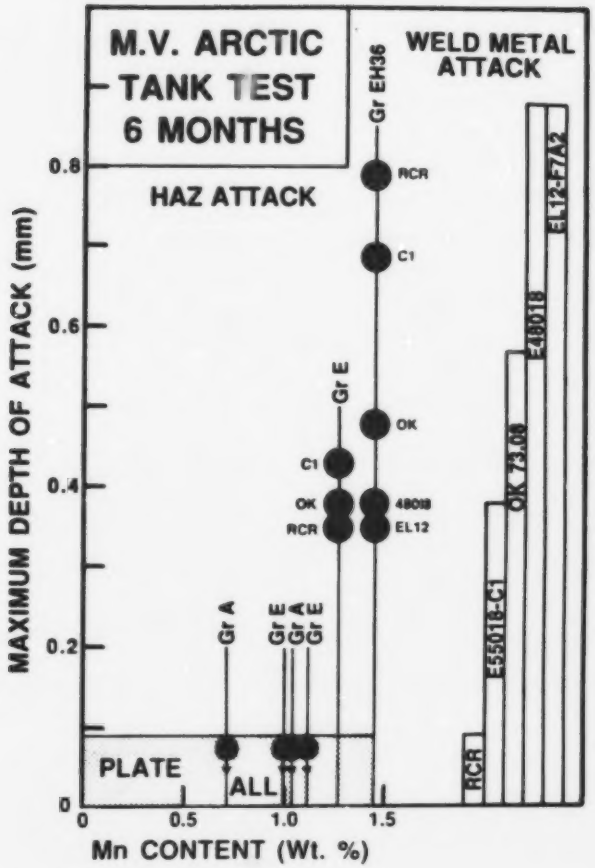


Fig. 3 Depth of attack in HAZ as a function of Mn content (Neg. 17576).